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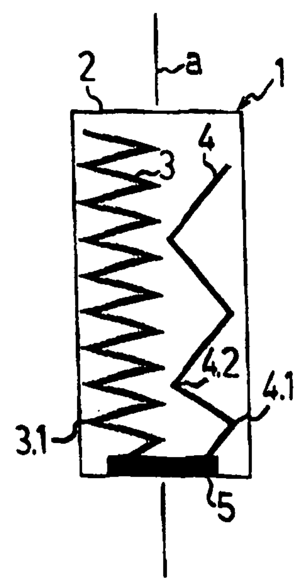
(54) Title: MULTIPLE BAND ANTENNA DEVICE

(57) Abstract

A multiple band antenna device (1) comprises a plate element (2), on which two antenna elements (3, 4) intended for transmitting and receiving are formed. They have a common feeding point (5) and are at least partially shaped into acute angles in zigzag, mutually facing acute angles (3.1, 3.2, ..., 4.1, 4.2, ...) in the two antenna elements (3, 4) within an arbitrary interval, which comprises at least one such acute angle (3.1, 3.2, ..., 4.1, 4.2, ...) in each antenna element (3, 4), being displaced in relation to each other and having different ascent. Moreover, the antenna elements (3, 4) are so tuned that the first element (3) has a first resonance maximum at a first frequency (f1) and the second antenna element (4) has a first resonance maximum at a second frequency (f2), which is at least twice as high as said first frequency (f1), the first antenna element (3) having a second resonance maximum at a third frequency (f3), which is lower than said second frequency (f2).



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MULTIPLE BAND ANTENNA DEVICE

The present invention relates to a multiple band antenna device for covering at least two frequency bands, which comprises a plate element, which is made of a dielectric material and on which a first antenna element intended for transmitting and receiving and a second antenna element intended for transmitting and receiving are formed, said antenna elements being situated beside each another in a main direction but having a common feeding point, which is connectable to an antenna terminal of a portable radio communication unit.

An antenna device of this type is shown in Fig. 3A in International Patent Application WO 97/49141. The antenna device in this figure comprises two parallel meander-shaped antenna elements, which are applied on a flexible plate-shaped carrier. The device is said to function well in the shown flat configuration, but is preferably intended to be formed into a cylindrical configuration. In comparison with a so-called double helical antenna, i.e. an antenna with two antenna elements helically wound round a common core, it is stated that a cylindrical antenna with the utilised meander-shaped elements has, in a comparable geometric separation, a lower degree of coupling between the individual elements and that this phenomenon is a great functional advantage in separated or wider frequency bands.

This phenomenon has previously been noted and the inventor of the present invention has directed special attention to it since a minimised degree of coupling between individual antenna elements facilitates the construction of small multiple band antenna devices, for which there is currently a demand in particular in small pocket telephones, which are intended for the two frequency bands 900 MHz and 1800 MHz, especially the latter requiring a very wide bandwidth due to relatively large

frequency differences between the telephone networks in different countries.

In the light of these facts, an object of the present invention is to provide a multiple band antenna device, which thanks to small dimensions and a high efficiency is suitable for use in pocket telephones and which moreover allows solutions with very wide bands in spite of a very low manufacturing cost.

This object is achieved with a multiple band antenna device of the type mentioned by way of introduction, which is characterised in that the antenna elements are at least partially shaped into acute angles in zigzag, mutually facing acute angles in the two antenna elements within an arbitrary interval, which comprises at least one such acute angle in each antenna element, being displaced in relation to each other in the main direction, the antenna elements in said interval having different ascent, and the antenna elements being so tuned that the first antenna element has a first resonance maximum at a first frequency f1 and that the second antenna element has a first resonance maximum at a second frequency f2, which is at least twice as high as said first frequency f1, the first antenna element having a second resonance maximum at a third frequency f3, which is lower than said second frequency f2.

In comparison with the antenna devices according to WO 97/49141, it has surprisingly been found that in particular in antenna elements which are shaped into acute angles in zigzag and mutually displaced in the above manner there is a minimised degree of inter-coupling, which considerably facilitates the construction of multiple band antenna devices, and that the efficiency, thanks to a distinct concentration of the radiated energy in the acute angles of the antenna elements, is significantly improved compared to a solution with round transitions or obtuse angles.

According to one embodiment, the second frequency f2 is at least 30% higher than twice said first frequency f1 to cover a third frequency band. Such an antenna device could be utilised e.g. for covering in an acceptable manner the currently used 900 MHz and 1800 MHz frequency bands in GSM systems as well as a future 2400 MHz frequency band.

However, to increase the bandwidth round the second frequency f2, the second frequency f2 is preferably twice as high as or maximally 10% higher than twice said first frequency f1. It will be appreciated that this is a suitable solution, in particular in the GSM field, since there can be a relatively great frequency dispersion on the 1800 MHz frequency band between different countries, but also within some countries, where efforts are made to obtain an increased capacity with the aid of a somewhat wider frequency band round 1800 MHz.

To be able to cover three different frequency bands or to provide an extreme bandwidth on a higher frequency band, a third antenna element, which is connected to the common feeding point and at least partially shaped into acute angles in zigzag, can be formed along the main axis beside the second antenna element, mutually facing acute angles in the second and the third antenna element, within an arbitrary interval which comprises at least one such acute angle in each antenna element, being displaced in relation to each other in the main direction, the antenna elements in said interval having different ascent, and the third antenna element being tuned so as to have a resonance maximum at a fourth frequency f4, which is higher than said second frequency f2. It will be appreciated that also such a relatively complicated multiple band antenna device, owing to the selected printed board technique according to the invention and the minimised degree of coupling between the antenna elements, is still very easy to design for the one skilled in the art and

that it can still have an extreme bandwidth in particular round the second frequency f2.

In the multiple band antenna device according to the invention, at least some of the mutually facing acute angles of two adjacent antenna elements can be tangent to or cut, each from one side, an imaginary line substantially parallel to the main direction. The advantage of such an antenna device is that it makes it possible to reduce the dimensions of the antenna device to an absolute minimum, which thanks to the selected zigzag configuration does not give rise to any substantial drawbacks in terms of efficiency.

According to another embodiment, at least one of the antenna elements can have a straight portion extending in the main direction between the feeding point and its zigzagged part. In this embodiment, the above-mentioned radiated energy is even more concentrated in the acute angles of the antenna element, as these in turn are concentrated in the end of the antenna due to the straight portion, at which end the radiation is always at its maximum. This results in a maximum efficiency at the sacrifice of somewhat greater dimensions of the antenna device and, if several antenna elements have a straight portion, somewhat greater difficulty in tuning the antenna elements due to their increased degree of intercoupling.

Preferably, the zigzagged part of at least one of the antenna elements has an ascent decreasing with an increasing distance from the feeding point. It will be understood that the object also of this solution is to maximise the efficiency of the antenna device by concentrating the radiated energy.

Moreover, the antenna elements on the plate element are preferably formed on a side which is facing away from a keypad side of a pocket telephone, on which the multiple band antenna device is mounted. Since the antenna elements according to the invention are placed on a plate

element and this plate element to a certain extent contributes to conferring a certain directionality to the inventive multiple band antenna device, it will be understood that it is suitable in a pocket telephone, where the antenna device is situated in the proximity of the user's head, to use this directionality to direct the radiated microwave energy away from the user.

In order to further minimise the energy radiated by a pocket telephone from the antenna device towards the user, it is moreover possible to manufacture the plate element of a material with a high dielectric constant ε, preferably a ceramic material with $\varepsilon > 8.0$ C/Vm.

Different embodiments of the multiple band antenna device according to the invention will be described below in more detail with reference to the drawings, in which:

Figs 1-3 illustrate three different circuitry configurations which are possible for a multiple band antenna device according to the invention;

Fig. 4 is a front view of a part of a pocket telephone with a multiple band antenna device according to the invention mounted on the same; and

Fig. 5 is a side view of the pocket telephone which includes the multiple band antenna device.

Fig. 1 shows a first embodiment of the inventive antenna device 1. It comprises a rectangular, flat plate element 2, which is made of glass fibre and on which circuitry of copper foil has been formed by etching. (The one skilled in the art will understand that neither the described selection of material nor the technique used to form the circuitry is of any vital importance and that, for instance, the plate element could instead be made of Teflon, that aluminium instead could be used in the circuitry and that screen printing could be used instead of etching.) The circuitry consists of a first antenna element 3, a second antenna element 4 and a so-called feeding point 5, which consists of a straight piece of copper foil along one short side of the rectangular plate ele-

ment 2 and which is intended to be connected to the antenna terminal of a pocket telephone in a manner described below in connection with Fig. 5. The antenna elements 3 and 4 extend along a common main direction a, which is parallel to the long sides of the rectangular plate element 2 in the illustrated example. Both of them are shaped into acute angles in zigzag, which in this case means that they are, so to say, folded with acute angles 3.1, 3.2,..., 4.1, 4.2... in the folding points, the folding points of the two antenna elements 3 and 4 not being located straight opposite each other.

It clearly appears from Fig. 1 that the two antenna elements 3 and 4 have different length measured from the feeding point 5. This is due to the fact that the antenna element 3 is intended for a lower frequency band and greater wavelengths than the other, shorter antenna element 4. The frequency bands can, for instance, be a 900 MHz frequency band and a twice as high 1800 MHz frequency band for GSM telephony. In the case of GSM frequency bands, it is important for the higher 1800 MHz frequency band to be covered in a wideband manner to suit mobile telephony standards in different countries, i.e. such that a transmitting and receiving range of e.g. 1710 to 1990 MHz is covered in a satisfactory manner. The antenna device 1 according to the invention fulfils these requirements by the first antenna element 3, for instance, being tuned at a first resonance frequency f1 of 900 MHz, which generates a second or a harmonic resonance frequency f3 at about 1800 MHz. However, the second resonance frequency is affected by the adjacent second antenna element 4 and therefore tends to be somewhat below twice the first resonance frequency f1, that is somewhat below 1800 MHz in the described example. The second antenna element 4 is therefore tuned so that it has, also under the action of the first antenna element 3, a first resonance frequency 12 which is somewhat higher, preferably maximally 10% higher, than the resonance frequency

f3 of the first antenna element 3 at 1800 MHz, which allows the antenna device to cover a very wide band round the frequency 1800 MHz.

This method of tuning and using two antenna elements is known per se, but the inventive design of the antenna elements has appeared to yield obvious advantages owing to the avoidance of parallel conductors between the two antenna elements as this design leads to a smaller degree of coupling between the antenna elements. This facilitates considerably the construction of multiple band antenna devices, in particular when very small antenna elements are to be provided. In addition, it has appeared that the inventive antenna device has an unusually high efficiency, which in the inventor's opinion is caused by the acute angles in the selected circuitry contributing to a certain concentration of the radiated energy. The one skilled in the art will understand that this is a great advantage in connection with pocket telephones, in which the limited battery capacity constitutes a factor to which the manufacturers pay a great deal of attention.

Fig. 2 shows a second embodiment of an inventive antenna device 1. This one also includes a rectangular plate element 2, on which circuitry of copper foil has been formed by etching. The circuitry consists of a first antenna element 3, a second antenna element 4, a third antenna element 8 and a common feeding point 5. The antenna elements 3, 4 and 8 extend in a common main direction a, the middle antenna element 4 being tangent to and cutting lines l parallel to the main direction a with some of its acute angles 4.1, 4.2,.... In addition, the antenna elements 3, 4 and 8, respectively, in Fig. 2 could each have a first resonance frequency of about 900 MHz, 1800 MHz and 2400 MHz, respectively, covering a very wide band round 1800 MHz and thus be suitable for a pocket telephone which can be used in a very flexible manner.

Fig. 3 shows a third embodiment of the inventive antenna device 1. It comprises a rectangular plate element 2, on which circuitry made of copper foil has been formed by etching. The circuitry consists of a first antenna element 3, a second antenna element 4 and a feeding point 5. The antenna elements 3 and 4 extend in a common main direction a, which is parallel to the long sides of the rectangular plate element 2. The antenna elements 3 and 4 have a part which is shaped into acute angles in zigzag and which has the inventive properties, and between this part and the feeding point 5 straight portions 3' and 4' each extending in the main direction a. The straight portion contributes to a great extent to the concentration of the radiated energy in the zigzagged part of the antenna elements, which is further enhanced by the antenna elements 3 and 4 in the zigzagged part having an ascent decreasing with an increasing distance from the feeding point 5. Since the coupling between the two straight and mutually parallel portions 3' and 4' is more distinct, it is an advantage if they are placed as far away from each other as possible in the shown manner. Moreover, with a view to increase the bandwidth covered by an antenna element, it can be an advantage if the zigzagged part as shown in connection with the antenna element 3 has a varying width or diameter which preferably increases with an increasing distance from the feeding point 5.

Figs 4 and 5 show a part of a pocket telephone 7, in which an inventive antenna device 1 is included. On its front side, the pocket telephone 7 has a keypad 9, which in normal use is turned towards a user. To shield the user to a certain extent from the microwave energy radiated during transmission from the pocket telephone 7, the antenna elements 3 and 4 and their common feeding point 5 are, as shown by the side view in Fig. 5, located on the side of the plate elements 2 of the antenna device facing away from the keypad 9. In addition, Fig. 5 illustrates

the antenna terminal 6 of the pocket telephone in the form of a soldering point which is connected with the feeding point 5.

It will be understood that the antenna device 1 can be designed in many different ways within the scope of the invention and that it does not have to include, as in Figs 4 and 5 where it is indicated by dashed lines, a completely flat plate element 2 or be contained in a casing protruding from a pocket telephone. Thus it may very well comprise a creased or otherwise suitably bent plate element 2 and, of course, also be completely integrated in the actual pocket telephone.

CLAIMS

1. A multiple band antenna device for covering at least two frequency bands, which comprises a plate element (2), which is made of a dielectric material and on which a first antenna element (3) intended for transmitting and receiving and a second antenna element (4) intended for transmitting and receiving are formed, said antenna elements (3, 4) being situated beside each other in a main direction (a) but having a common feeding point (5), which is connectable to an antenna terminal (6) of a portable radio communication unit (7), characterised in that the antenna elements (3, 4) are at least partially shaped into acute angles in zigzag, mutually facing acute angles (3.1, 3.2, ..., 4.1, 4.2,...) in the two antenna elements (3, 4) within an arbitrary interval, which comprises at least one such acute angle (3.1, 3.2, ..., 4.1, 4.2,...) in each antenna element (3, 4), being displaced in relation to each other in the main direction (a), the antenna elements (3, 4) in said interval having different ascent, and the antenna elements (3, 4) being so tuned that the first antenna element (3) has a first resonance maximum at a first frequency f1 and that the second antenna element (4) has a first resonance maximum at a second frequency f2, which is at least twice as high as said first frequency f1, the first antenna element (3) having a second resonance maximum at a third frequency f3, which is lower than said second frequency f2.

2. A multiple band antenna device according to claim 1, wherein the second frequency f2 is at least 30% higher than twice said first frequency f1 to cover a third frequency band.

3. A multiple band antenna device according to claim 1, wherein, to increase the bandwidth round the second frequency f2, the second frequency f2 is twice as

high as or maximally 10% higher than twice said first frequency f1.

4. A multiple band antenna device according to claim 3, wherein a third antenna element (8), which is connected to the common feeding point (5) and at least partially shaped into acute angles in zigzag, is formed along the main axis (a) beside the second antenna element (4), mutually facing acute angles (4.1, 4.2,..., 8.1, 8.2,...) in the second and the third antenna element (4, 8), within an arbitrary interval which comprises at least one such acute angle (4.1, 4.2,..., 8.1, 8.2,...) in each antenna element (4, 8), being displaced in relation to each other in the main direction (a), the antenna elements (4, 8) in said interval having different ascent, and the third antenna element (8) being tuned so as to have a resonance maximum at a fourth frequency f4, which is higher than said second frequency f2.

5. A multiple band antenna device according to any one of claims 1-4, wherein at least some of the mutually facing acute angles (3.1, 3.2,..., 4.1, 4.2, ..., 8.1, 8.2,...) of two adjacent antenna elements (3, 4, 8) are tangent to or cut, each from one side, an imaginary line (l) substantially parallel to the main direction (a).

6. A multiple band antenna device according to any one of the claims 1-5, wherein at least one of the antenna elements (3, 4) has a straight portion (3', 4') extending in the main direction (a) between the feeding point (5) and its zigzagged part.

7. A multiple band antenna device according to any one of claims 1-6, wherein the zigzagged part of at least one of the antenna elements (3, 4) has an ascent decreasing with an increasing distance from the feeding point (5).

8. A multiple band antenna device according to any one of claims 1-6, wherein the antenna elements (3, 4, 8) on the plate element (2) are formed on a side which is facing away from a keypad (9) side of a pocket telephone

(7), on which the multiple band antenna device (1) is mounted.

9. A multiple band antenna device according to claim 8, wherein the plate element (2) is made of a material with a high dielectric constant ε, preferably a ceramic material with ε greater than 8.0 C/Vm.

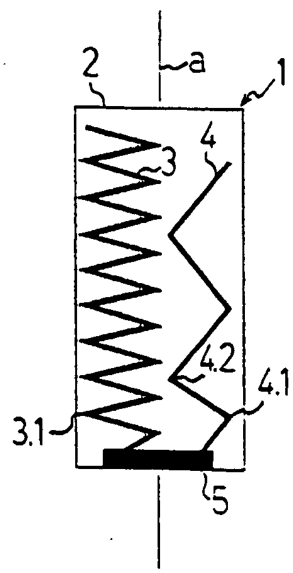

FIG 1

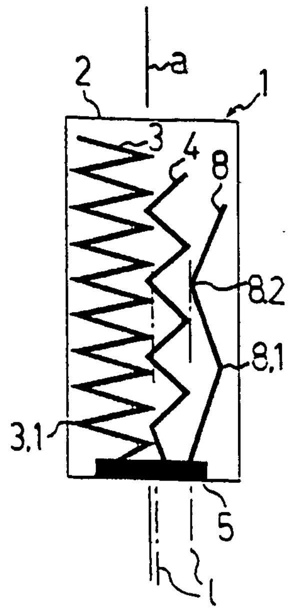

FIG 2

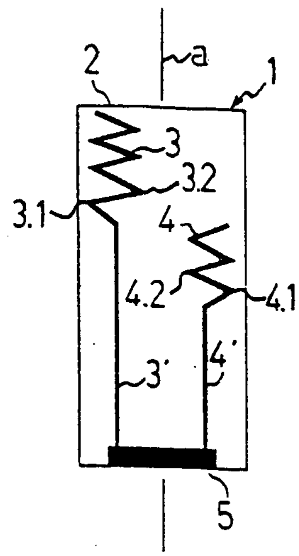

FIG 3

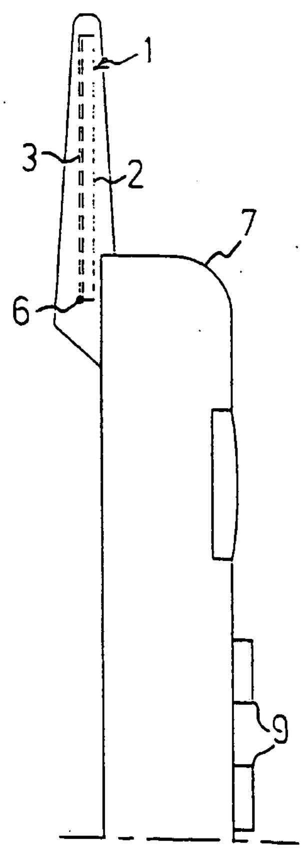

FIG 5

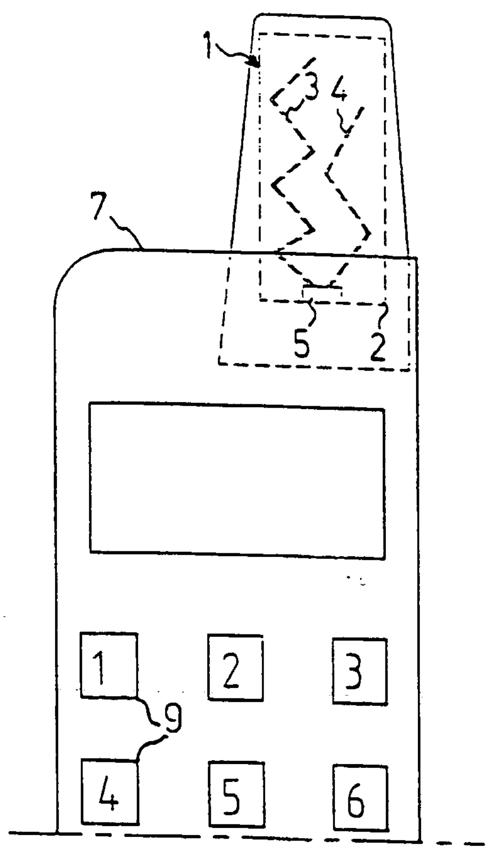

FIG 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/00658

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H01Q 1/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9749141 A1 (ALLGON AB), 24 December 1997 (24.12.97), page 8, line 20 - line 34, figures 2C, 3A, abstract --	1-9
A	WO 8502719 A1 (MOTOROLA, INC.), 20 June 1985 (20.06.85), figures 2,4, claim 1, abstract -- --------	1-9

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information on patent family members

30/08/99

International application No.
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9749141 A1	24/12/97	AU 3280897 A	07/01/98
		EP 0904611 A	31/03/99
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